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A Bibliography on the Corrosion and Protection of Steel in Concrete

E. Escalante and S. Ito*

This is a bibliographic list of references of published papers, reports, and talks about the corrosion of steel in concrete and related subjects. The references are presented in two forms: 1) a subject index divided into six major subheadings including reviews, factors affecting corrosion, measurement techniques, protection techniques, concrete design, and related fields, and 2) an author index in alphabetical form. A total of 394 references are listed covering the period from 1964 to November 1978.

Key words: Bridge deck; concrete; corrosion; corrosion of steel; rebar corrosion; reinforced concrete.

1. Introduction

The corrosion of steel in concrete and the resulting damage to structures continue to be a problem of increasing magnitude. The situation is further aggravated where deicing salts containing chlorides are used, and it is of particular concern in the case of highway bridge decks. Too often the corrosion of steel causing the concrete structure to deteriorate is evident only after extensive damage has occurred. As new designs in materials and construction are used, a system should be developed for evaluating the deterioration of the steel before structure failure occurs.

Considerable research has been conducted on the corrosion of steel in concrete. The effect and interaction of pH, chloride concentration, moisture content, and oxygen in concrete have been investigated by various groups, but because of the complexity of the problem, many questions remain unanswered.

This is a survey report on the literature of the corrosion of steel in concrete covering the period from 1964 to November 1978. The references are presented in two forms. First is a Subject Index in which the references are identified by a number under subheadings. These numbers refer to the second form of the references which is an alphabetical listing of the authors numbered from 1 to 394 entitled Author Index.

The Subject Index is divided into six subheadings which are listed and described as follows:

I. General Survey and Review (14 entries)

Over the past 10-15 years, the deterioration of concrete structures has increased considerably. The 1969 annual total cost estimated for restoration and protection of bridges on the interstate road system was $2.6 billion. These entries describe the different environments that concrete structures encounter in a stressed and unstressed condition and case histories of problems that have developed.

II. Research on Factors Affecting the Corrosion of Steel in Concrete (111 entries)

The corrosion of steel in concrete is a complex phenomenon. However, four factors can be identified as having a direct effect on the observed deterioration. These are, 1) pH of the concrete, 2) chloride concentration, 3) oxygen concentration, and 4) moisture. This index reveals that many studies have been conducted on chloride and its effects while considerably less work has been reported on the effects of pH, oxygen, and moisture. Furthermore, stress corrosion of steel in concrete has not been reported to be a serious problem in the United States as it has in other countries.

Questions remain on just how the above factors interact with each other resulting in the corrosion of steel in concrete.

III. Detection and Measurement Techniques (22 entries)

Evaluating the corrosion of steel in concrete before external signs show has been difficult. An empirical technique widely used is making half cell potential measurements over the surface of a bridge deck. More recently other techniques, such as ac impedance and the various polarization methods have been reported as showing promise in laboratory studies. Commercial instrumentation is now available for evaluating the deterioration of small metal probes that can be imbedded in concrete in close proximity to the metal of interest.

IV. Corrosion Protection Techniques (75 entries)

A variety of corrosion protection systems have been developed. These range from modifications of the chemistry of the concrete to isolating the steel from its environment through the use of coatings. Electrochemical techniques such as cathodic protection have also been used. The application of a satisfactory protection system to an existing structure is yet to be developed though some advances have been reported.

V. The effect of Concrete Mixture, Admixture, and Structural Design on the corrosion of steel (107 entries)

The environment in which the structural steel finds itself is the dominating factor in the resulting corrosion that it suffers. Already mentioned are some of the chemical parameters that are a part of this environment. It has been reported that the design of the concrete mixture has a very important influence on these parameters. The entries in this section discuss the effect of water to concrete ratios, additives that serve as barriers to chloride, shrinkage compensation, and others.

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VI. Other fields Relating to the Corrosion of Steel in Concrete (31 entries)

The experiences gained in other areas such as offshore concrete structures, desalination plants, reinforced concrete roofs are valuable. The conditions to which some of these structures are subjected are sometimes far more severe than those found on a bridge deck. The solutions to their problems can be useful in gaining a further insight to the corrosion of steel in concrete.

A large portion of the references were taken from the National Technical Information Service (NTIS) data base on corrosion of reinforced concrete. These references are identified by an AD or PB identification code. Other references have been taken from the engineering data base also published by NTIS, Springfield, VA. The remainder, and the most up to date references, have been obtained through manual and computer searches here in the National Bureau of Standards Library.

2. Subject Index

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This is a bibliographic list of references of published papers, reports, and talks about the corrosion of steel in concrete and related subjects. The references are presented in two forms: 1) a subject index divided into six major subheadings including reviews, factors affects corrosion, measurement techniques, protection techniques, concrete design, and related fields, and 2) an author index in alphbetical form. A total of 394 references are listed covering the period from 1964 to November 1978.

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